Hardening Aircraft Against Terrorist Threats

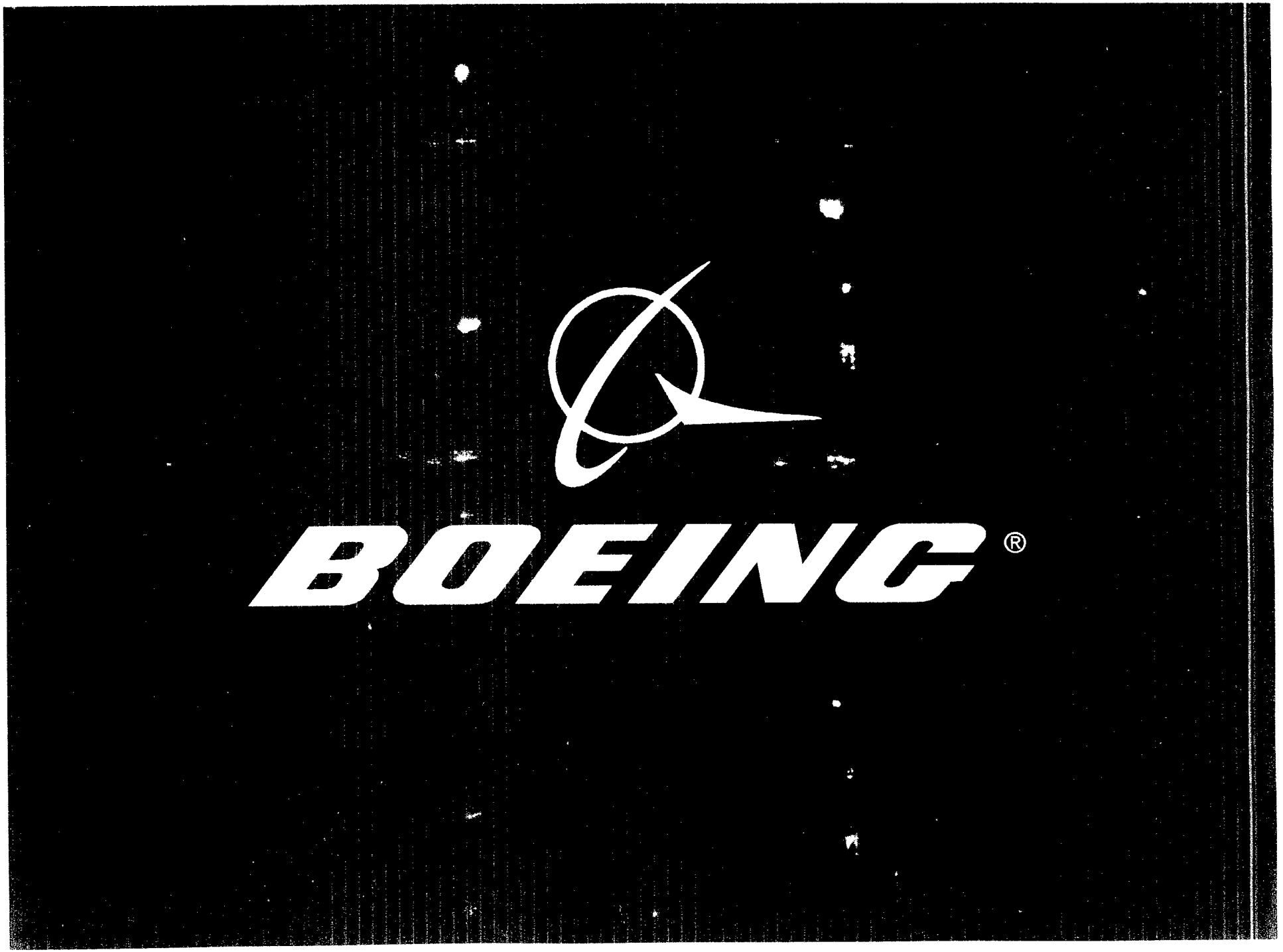
330

John Kuhn
Project Manager, WABT

Chantal Joubert
Manager,
Aircraft Protection,
Safety and Regulatory

Victor Chen
Project Manager, RBTF

ADPA Conference, Monterey
October 22, 1997


BOEING®

Participation in FAA Aircraft Hardening Program

(Completed)

- Development of Aircraft Structural Response Methodology
- Aircraft Response to Internal Explosive Detonation

(Ongoing)

- Wide Body Aircraft Blast Test
- Reusable Blast Test Fixture

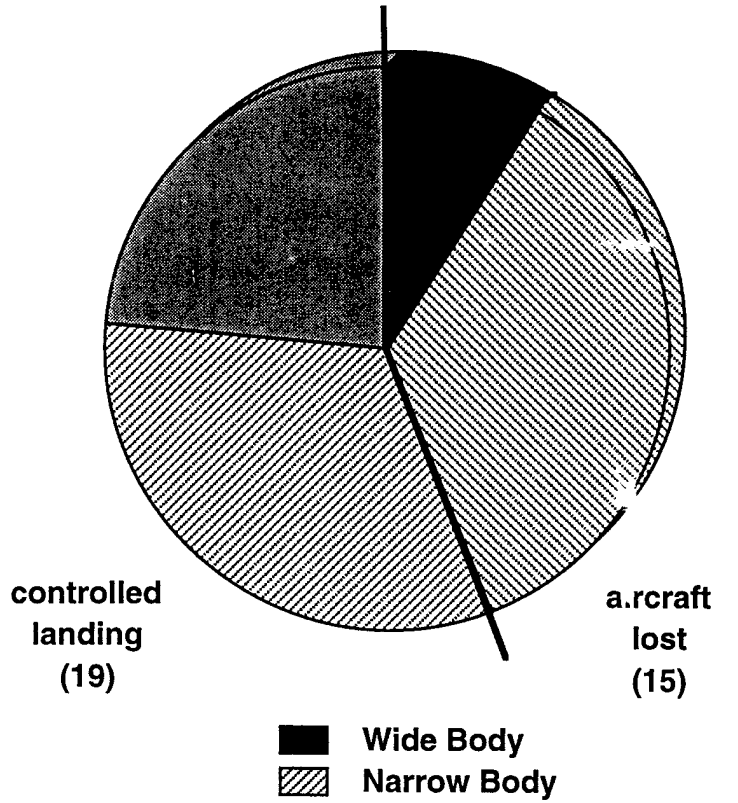
BOEING®

Aircraft	Bombing Attempts	Blast Events			% Survive Attempts	% Survive In-flight Blast
		Total	In flight	Catastrophic		
Total	81	58	34	15	81%	56%
Narrow-body	58	43	23	12	79%	48%
Wide-body	23	15	11	3	87%	73%
U.S. Events	10	4	1	0	100%	100%

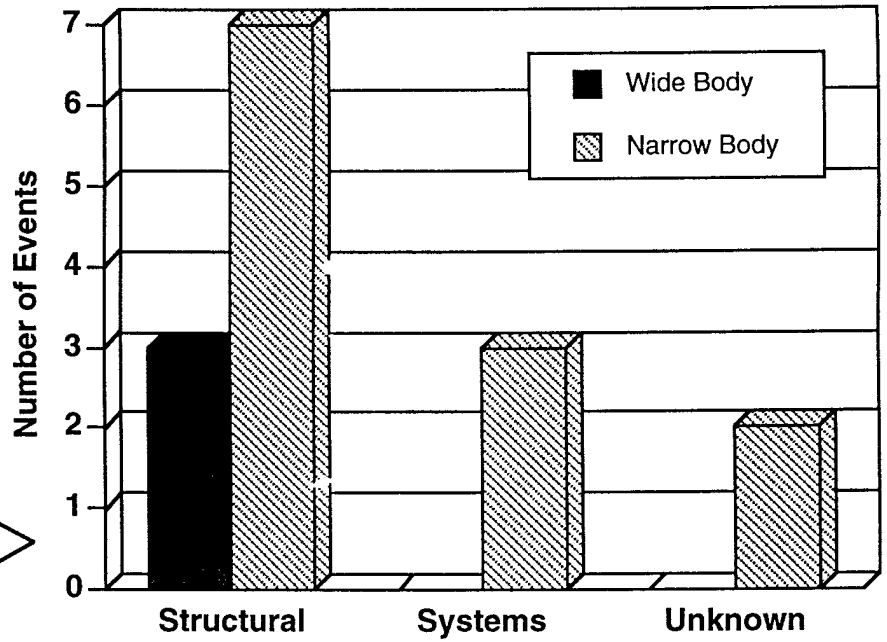
BOEING

In-Flight Bomb Blast Events
1971 - 1995

Event Outcome of 34 In-Flight Incidents



Failure Modes of 15 Aircraft Lost



BOEING

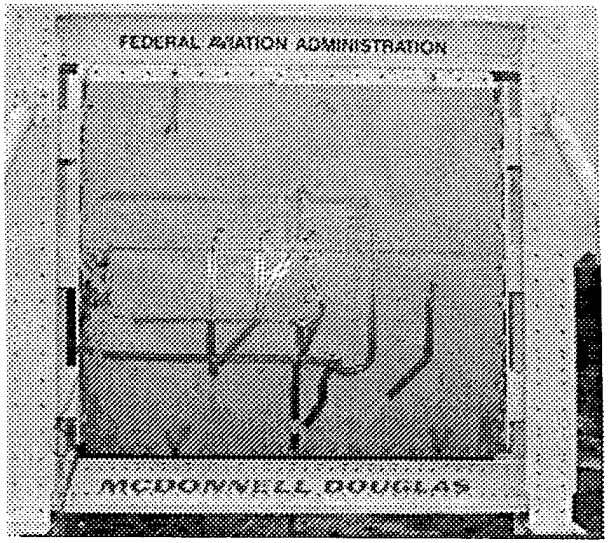
DGPro/Incident Data Summary (#4) (disk)
Mac/pb/9/13/95

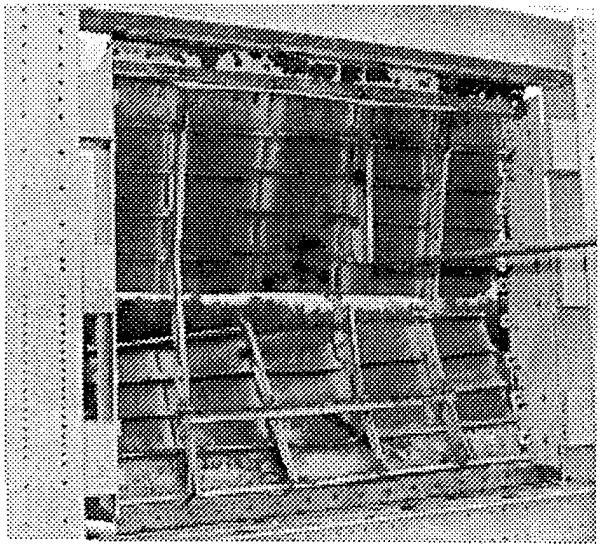
Bombings Against Commercial Aviation
Findings

- Bombings against commercial aviation are a worldwide problem.
  - Has already involved 33 countries and 40 airlines.
- Terrorists have knowledge of new methods to build bombs that may be more difficult to detect.
- 56% of aircraft survive in-flight bombings.
- Wide-body aircraft have a greater inherent tolerance to in flight bombings and 73% survive, compared to 48% of narrow-bodies.
  - Greater internal volume to absorb the blast
  - Greater structural surface area and multiple load paths to dissipate blast loads
  - Greater opportunity for separation of redundant systems

BOEING

Aircraft Hardening Program Materials Properties Database

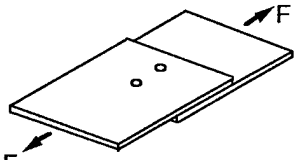




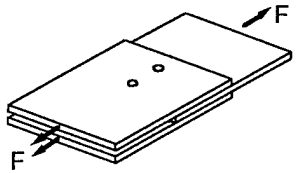
PANEL TESTING

- Mode I fracture toughness for 0.71 in. 2024-T3
- Rate-dependant constitutive relations (full range stress-strain diagrams)

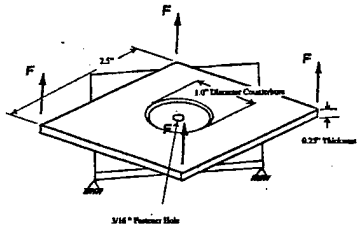
DYNAMIC MATERIALS PROPERTIES



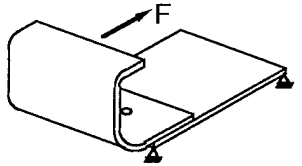
Single Shear



Double Shear

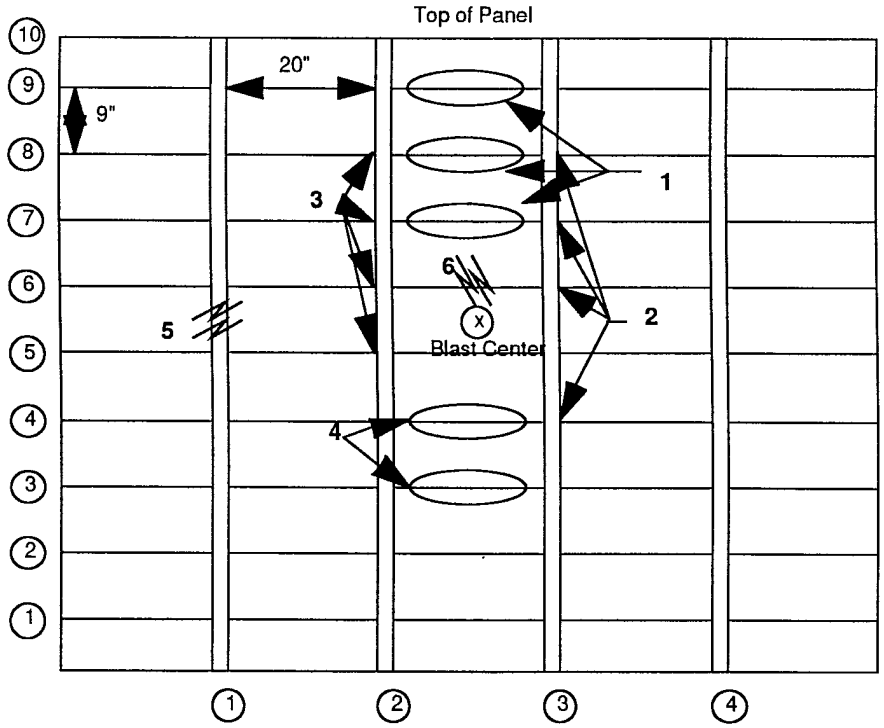


Tension



Peeling load

COMPONENT LEVEL TESTING



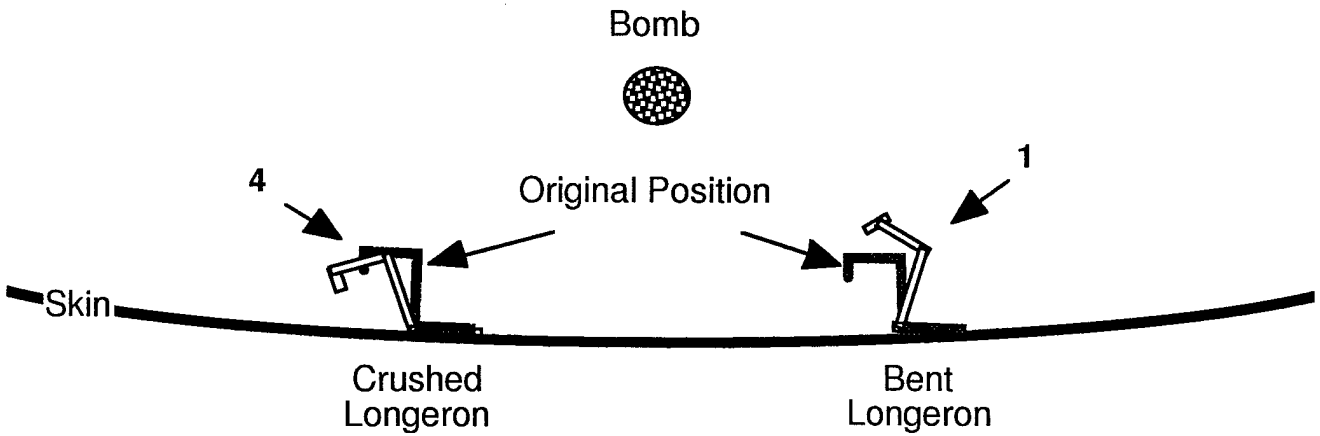
Frames

Longerons

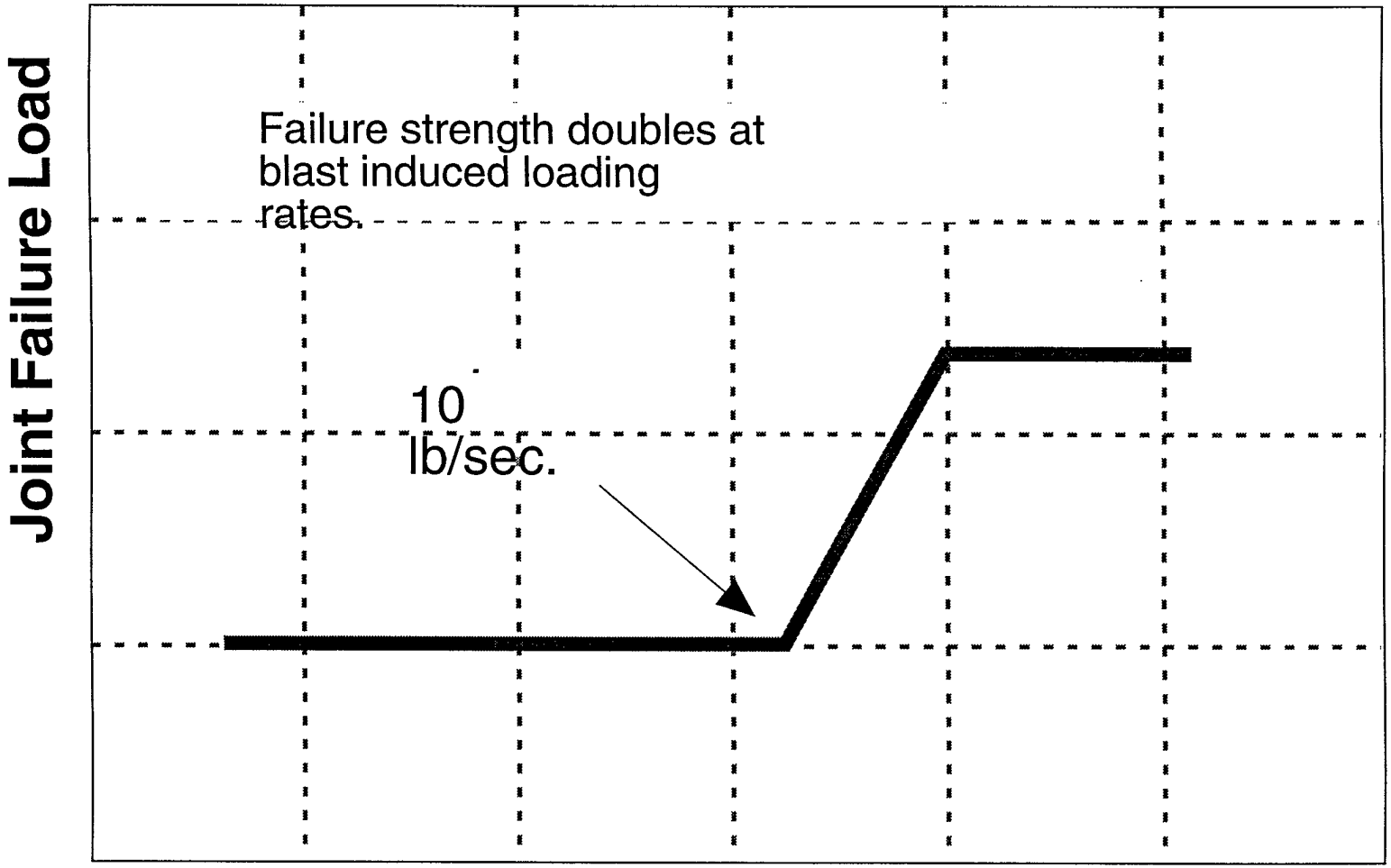
Broken structure

Damage Description :

1 Areas where the longerons are bent upward, away from the blast wave.
2 Cleats between the frame and longeron broken.
3 Cleats between the frame and longeron broken.
4 Longerons slightly crushed from blast wave.
5 Frame 1 cracked in Mode III.
6 Longeron 6 also broke in Mode III, small area broken out.

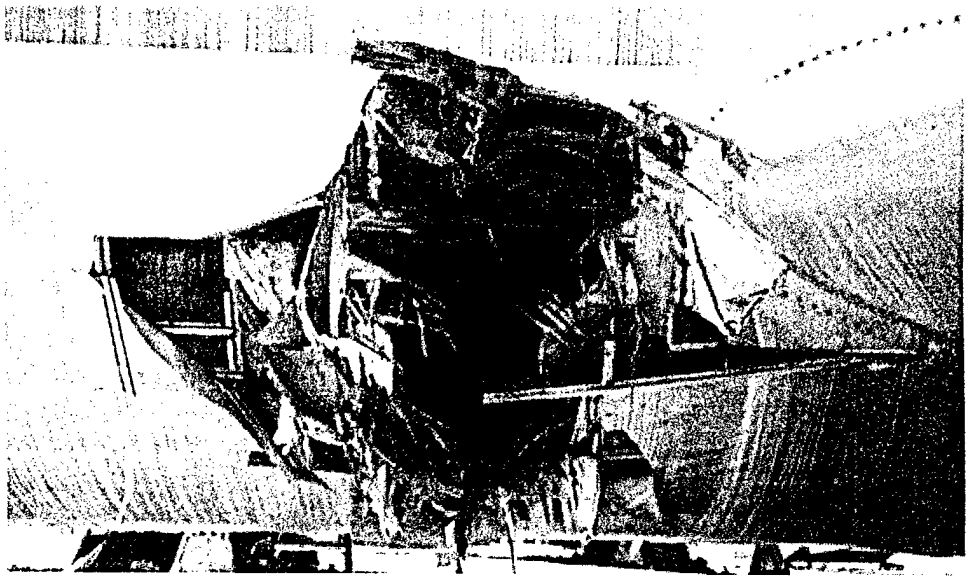


Typical Test Results

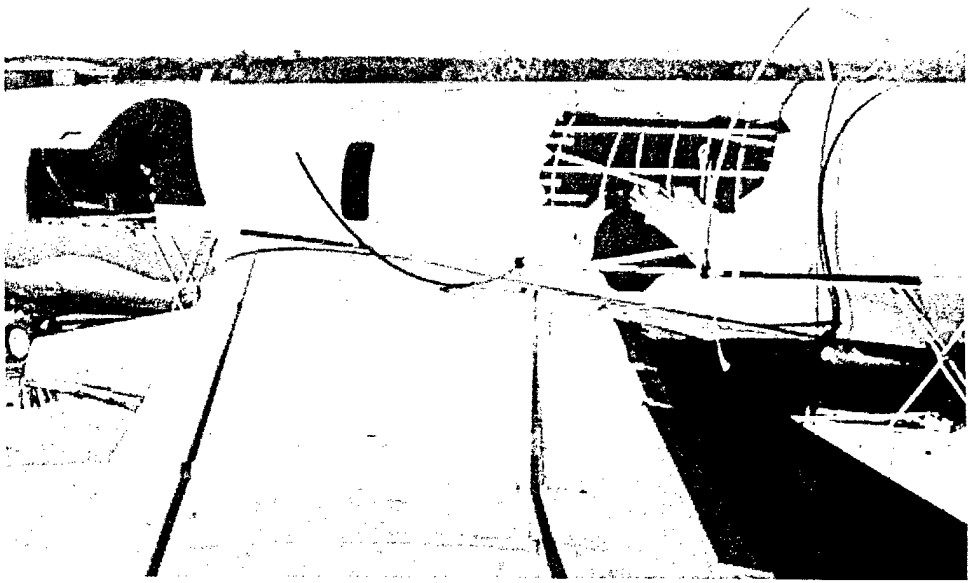


BOEING

Aircraft Hardening Program Aircraft Test Database



B-707 Parametric Tests



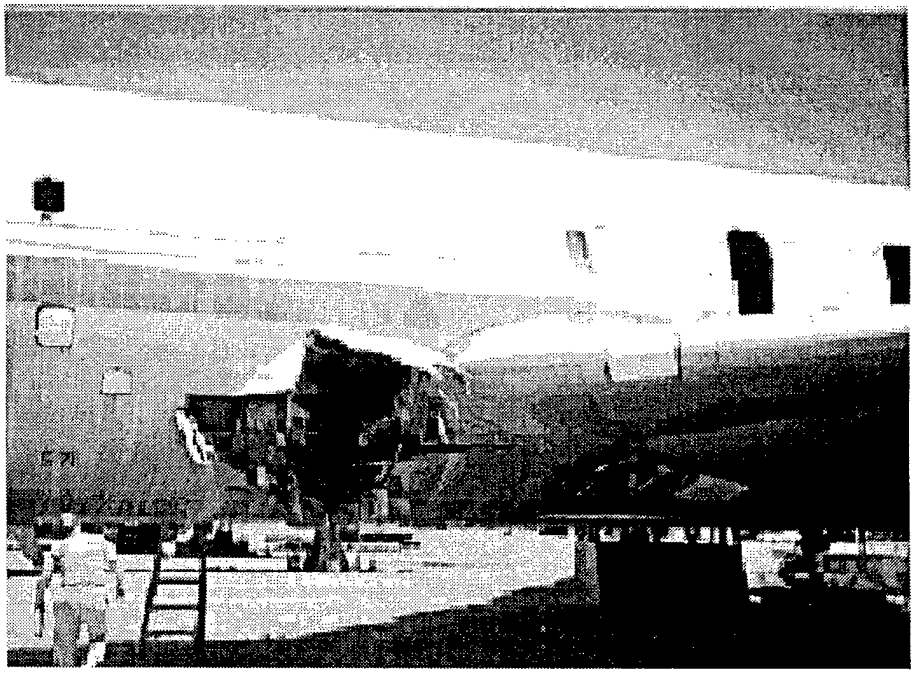
KC-135 Pressurization Tests

C-880 Systems Vulnerability Tests

LD-3 Fragmentation Tests

B-707 Narrow-Body Aircraft Tests
Comparison of Damage Modes

Blast Damage from a Bare Charge



Blast Damage from a Fragmentation Charge
(Single Suitcase)

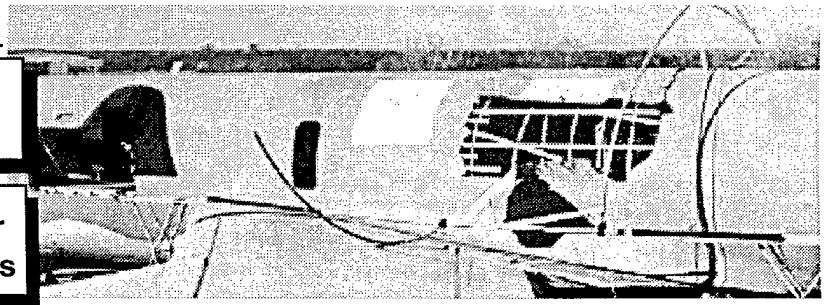
BOEING®

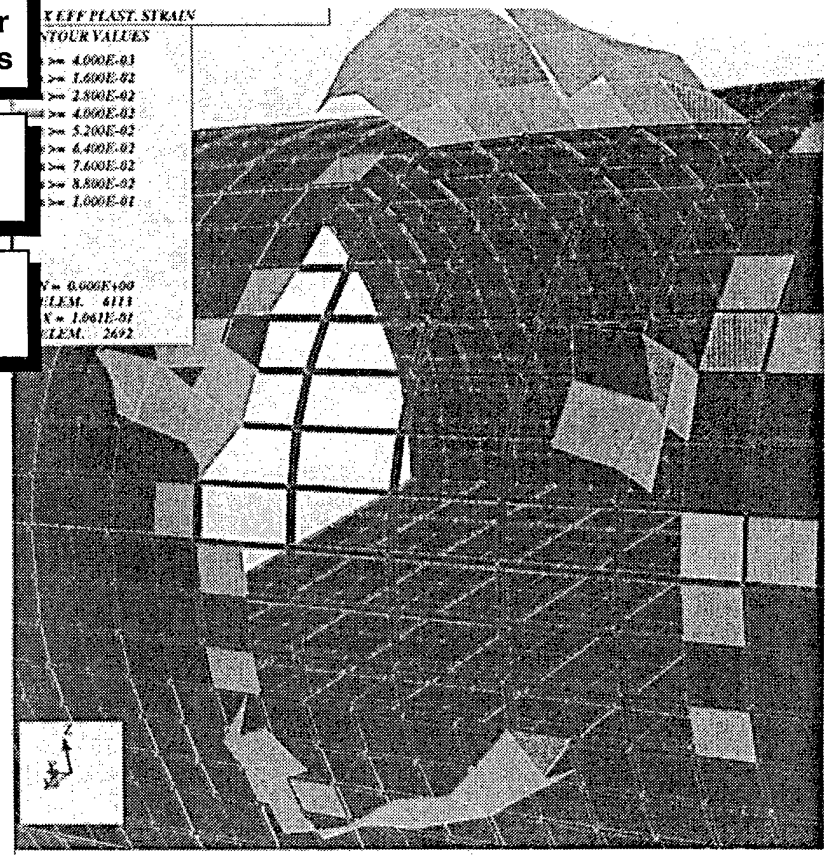
Pressurized vs. Non-Pressurized C-880 Test

LD-3 Threat Characterization Test Series

Integrated Structural Response Methodologies

Pressure Loading	Initial Response	Damage Growth
Empirical Methods		Critical Impulse
INBLAST or eq. PC-codes	Equiv. Static Pressure	Implicit FE codes or close-form solutions
INBLAST or eq. PC-codes	Uncoupled Transient	Implicit FE codes or Freq. Dom. Analysis
Hydrocode (explicit transient FE codes)		Implicit FE codes
Hydrocode: Enhanced PAM-SHOCK/PAM-FLOW		





- Pam codes analysis of KC-135 pressurized bare charge blast tests
- Next step - Add fragmentation effects from LD-3 and luggage

Wide-Body Aircraft Blast Test

L-1011, Mobile Alabama

PROGRAM OBJECTIVE:

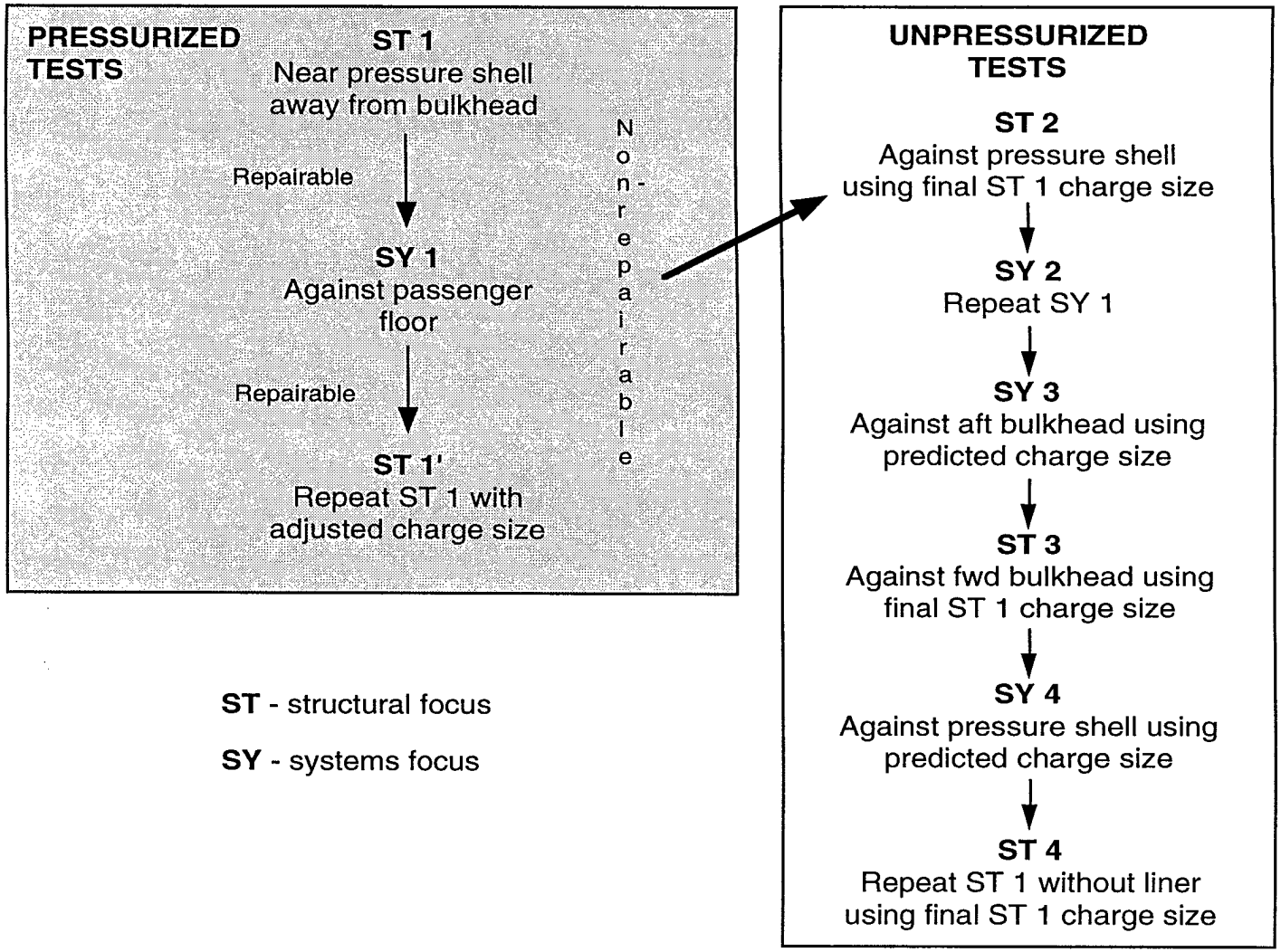
To determine the minimum charge size and charge location to cause catastrophic damage, to a wide-body aircraft, from a bomb placed in a LD-3 luggage container.

BOEING

Test Simulates Operational Environment

- Charge placed within luggage within LD-3 Container
- Container surrounded by other containers, all 75% full
- Representative delta pressures (~8.4 psi)

Test Plan

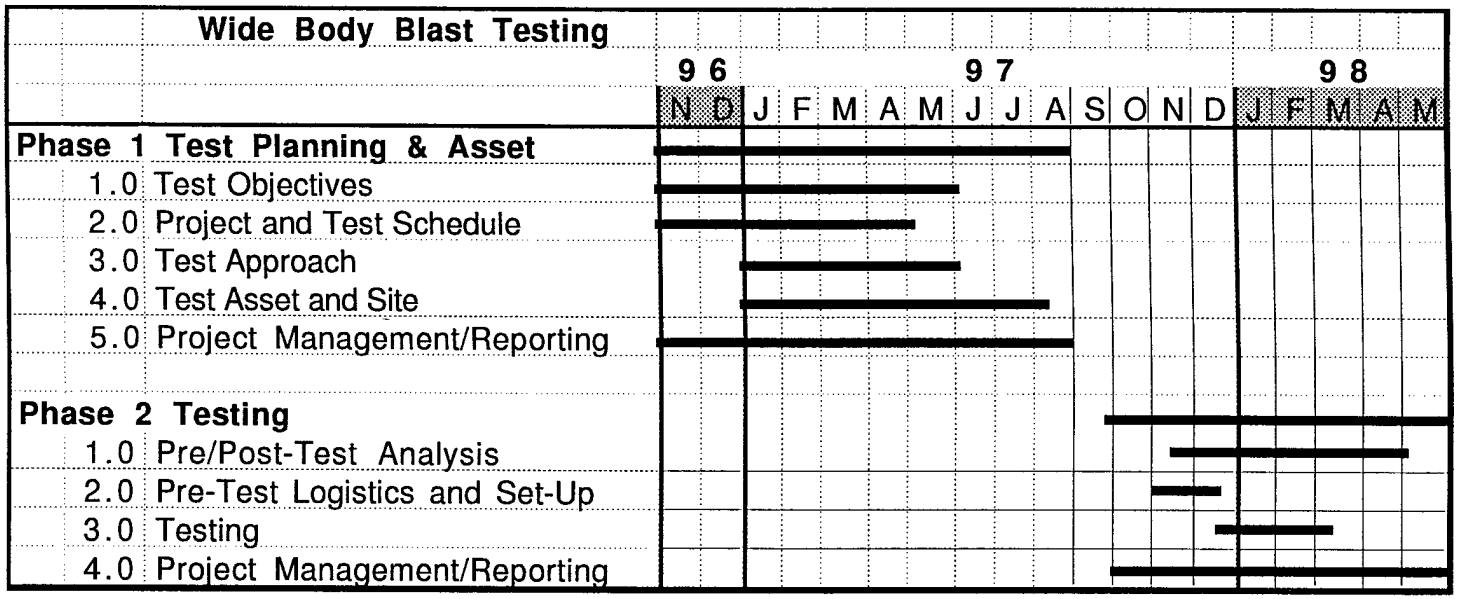


ST - structural focus

SY - systems focus

BOEING

Program Schedule



Boeing Activities

Aircraft Preparation
Test Configuration
Instrumentation
General site support
Test Documentation and Analysis

FAA Activities

Explosives Handling
Photo/Film

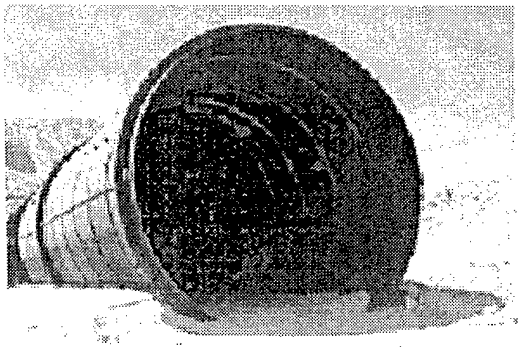
BOEING

Reusable Blast Test Fixture

Objectives

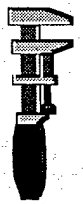
- To provide an asset for gathering repeatable, realistic blast test data.
- To assess/verify hardening concepts; in particular, hardened containers.

Reusable Blast Test Fixture



EXISTING SHOCK TUBE

FIXTURE DESIGN



FABRICATION

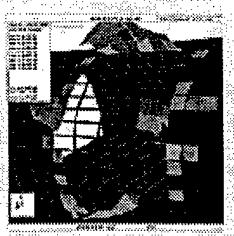
NMT

EXPLOSIVE HANDLING
AND TESTING

PROGRAM

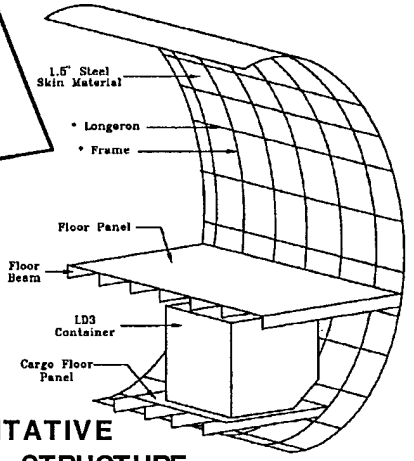
TEST
PLAN

REQUIREMENTS
ANALYSIS



DESIGN ANALYSIS

TEST SECTION
DESIGN



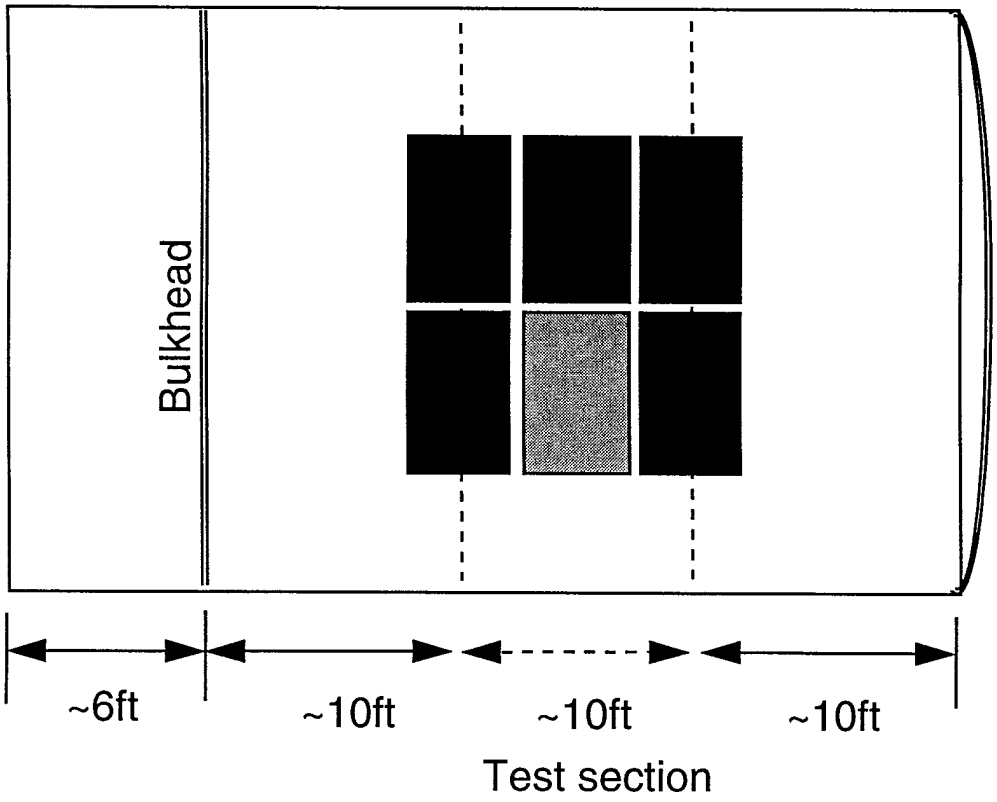
REPRESENTATIVE
AIRCRAFT STRUCTURE

Boeing

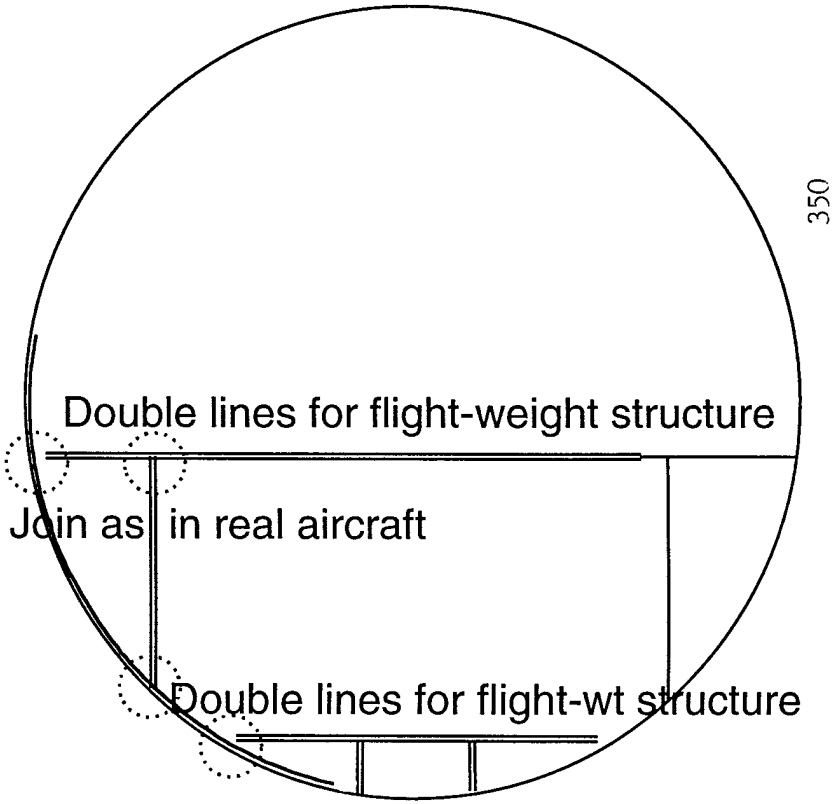
BOEING®

RBTF Basic Design Concept 1

Top View



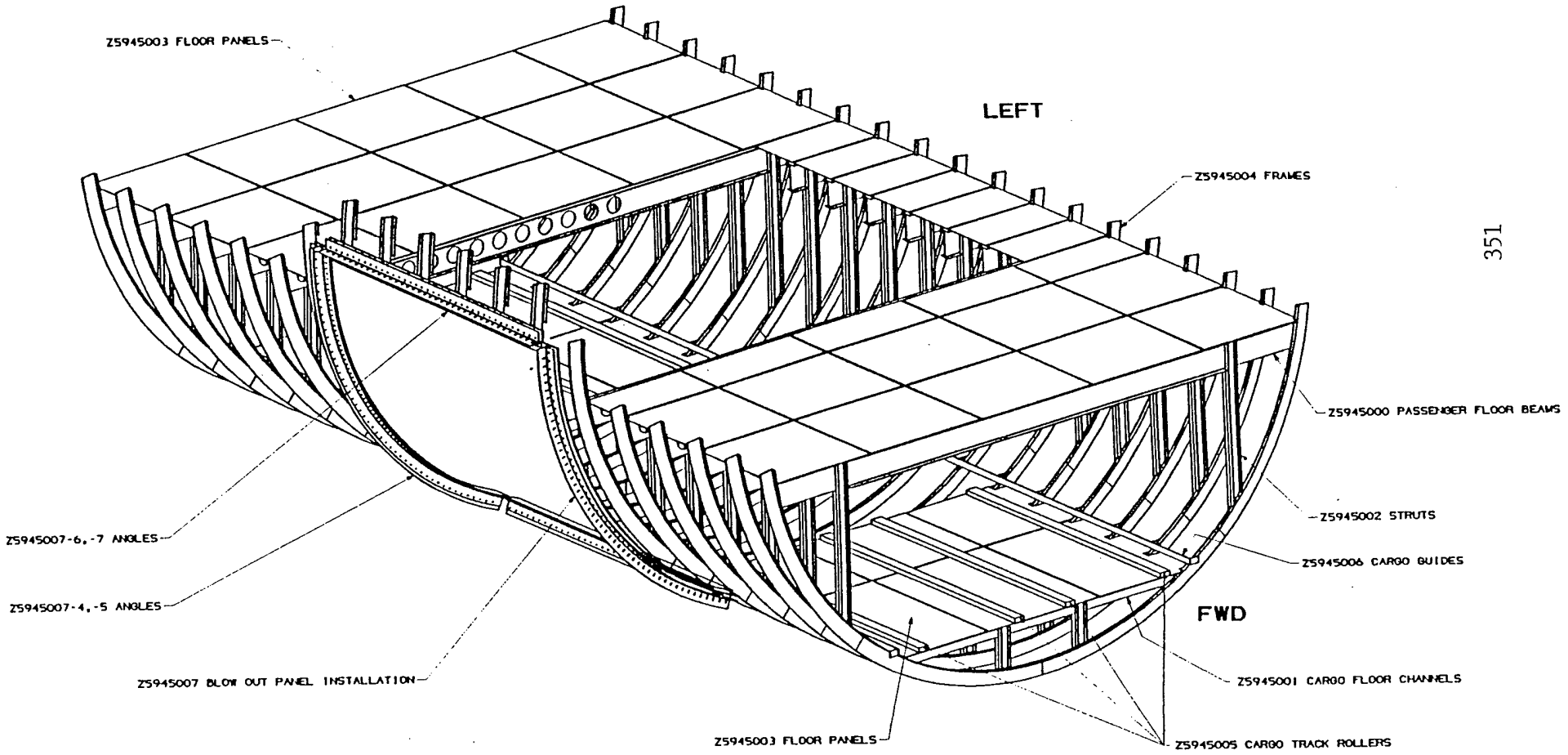
End View of Test Section



350

BOEING®

RBTF Basic Design Concept [2]



Adding this steel design to an existing 20'-D shock-tube creates a low-cost RBTF. – The opening will be fitted with flight-weight test sections.

Status

- Design Requirements Document Published
- PDR on 2/12/97
  - All parties satisfied with design
  - Decision to initiate fabrication prior to CDR
- Design Drawing and Analysis of Fixture Design Completed
  - Aircraft Section Patch to RBTF with M/S ~ 3
- CDR on 5/9/97
- Anticipate completion of fixture fabrication in October 97

Summary

- Developing data and tools to properly assess threats and aircraft response to threats.